

(19) JAPANESE PATENT OFFICE (JP)

(11) Disclosure Number:  
**H3-243286**

(12) Patent Disclosure Bulletin (A)

(51) Int. Cl.<sup>5</sup>  
B 23 K 20/12

ID Symbol  
G

Internal Admin. No.  
7147-4E

(43) Disclosure Date:  
October 30, 1991

Examination Requested

Not yet

Number of Claims: 3 (Total 7 pages)

(54) Title of Invention      Joining Method for Clad Tube

(21) Application Number    H2-41637

(22) Application Date      February 22, 1990

(72) Inventor                UCHIDA, Masakatsu  
44-17 Inuyama-cho, Sakae-ku, Yokohama-shi, Kanagawa-ken

(72) Inventor                TOMIKAWA, Mizukado  
1-24-4 Koujimanishi, Minatokita-ku, Yokohama-shi, Kanagawa-ken

(71) Applicant              Chiyoda Corp.  
2-12-1 Tsurumi Chuo, Tsurumi-ku, Yokohama-shi, Kanagawa-ken

(74) Agent                  MATSUMOTO, Hidetoshi and 1 other

### Specifications

1. TITLE OF INVENTION  
Joining Method for Clad Tube

2. Scope of Patent Claims

What is claimed:

Claim 1

A clad tube joining method for clad tubes with an outer metal layer cladded on the inner side with an inner metal layer which is thinner than said outer metal layer, joined together on an identical center axis, wherein the clad tubes to be joined have a U-shaped groove on the ends to be joined, and friction contact is started between the inner metal layers of the clad tubes to be joined, and then both clad tubes are pressure welded together.

Claim 2

The clad tube joining method claimed in Claim 1, wherein said U-shaped grooves have a groove angle greater than 15° and less than 45°.

**BEST AVAILABLE COPY**

### Claim 3

The clad tube joining method claimed in Claim 1 or Claim 2 wherein said outer metal layer is made from carbon steel or chrome molybdenum steel, and said inner metal layer is made from stainless steel or nickel alloy steel.

## 3. DETAILED DESCRIPTION OF THE INVENTION

### INDUSTRIAL FIELD OF APPLICATION

This invention relates to a method for joining the circumferential seams of clad tubes.

### PRIOR ART

Clad tubes which are clad on the inside by a corrosive resistant metal layer are used to provide corrosion resistance to tubes.

For instance, chemical factories use clad tubes where the inside of a carbon steel or molybdenum steel is clad with a stainless steel or nickel alloy steel. When these types of clad tubes are used, the costs can be lower than when the whole tube is made from carbon steel or chrome molybdenum steel. Furthermore, when the whole tube is made from carbon steel or chrome molybdenum steel, cracks will easily penetrate in the material thickness direction when stress corrosion cracks form from the inner surface of the tube, but when clad tubes are used, cracks can be prevented from penetrating through.

The joining of clad tubes has primarily been performed by arc welding in the past. Clad tubes generally have a outer diameter less than 8 inches (216 mm), so arc welding from the outer side of the tube is required. Therefore, welding was performed in the past by making a groove in the joint region of the clad tubes and filling the inside of the joint with weld metal when the clad tubes are facing each other, so that the weld metal layer is successively formed from the inside to the outside.

Fig. 8 schematically shows the cross-section of the joint region between clad tubes 1, 1' which are joined by arc welding, and in this figure, 1a, 1a' represent the external metal layer made from carbon steel or chrome molybdenum steel, and 1b, 1b' represent the inner metallic layer made from stainless steel or nickel alloy steel.

When these types of clad tubes are welded, it is necessary for the first layer 2 to be made of stainless steel or nickel alloy steel in order to maintain corrosion resistance. It is possible to consider making all layers in the joint region of stainless steel or nickel alloy steel, but if all layers are made from stainless steel or nickel alloy steel, cracks created from stress corrosion can easily penetrate. Therefore, upper layer 4 must be filled with carbon steel or chrome molybdenum steel. However, when welding carbon steel or chrome molybdenum steel directly over an initial layer of stainless steel or nickel alloy steel, part of the stainless steel or nickel alloy steel will melt and mix into the layer of carbon steel or chrome molybdenum steel, forming a weak weld alloy of martensite in the boundary region, and reducing the weld strength. In the past, in order to prevent this, an intermediate layer 3 made up of pure steel or very low carbon

steel was established between the initial layer 2 and the upper layer 4.

As shown in Fig. 8, when clad tubes are welded together by arc welding, the intermediate layer 3 will become very hard (Vickers hardness of 350 ~ 450), so there is a problem with a drop in ductility of the welded region. Furthermore, there is also problem that when there is a high temperature hydrogen environment in the tube, the intermediate layer 3 will easily weaken. Also the weld operation for arc welds is complex, and therefore it is expensive and requires skill to perform.

Consequently, joining clad tubes by friction pressure welding has been investigated. According to previously known friction pressure welding methods, the procedures for welding clad tubes is as follows.

As shown in Fig. 9, one clad tube 1 is secured in a stationary side clamp and the other clad tube 1' is clasped in the chuck of the main rotationally driven shaft, such that the pressure weld surfaces A, A' of clad tubes 1, 1' are orthogonal surfaces to the axial directions of the clad tubes. Next, the rotating side clamp tube 1' is rotated while one clad tube is pressed onto the other clad tube at a designated pressure (known as the heating pressure) by a pressing mechanism, and the joining regions of both tubes are heated by friction. When the temperature of the joining regions reaches the designated temperature the clad tube 1' on the rotating side is stopped and the clad tubes 1, 1' are pressed together at a high upset pressure using a pressing mechanism, to form a pressure weld.

Fig. 10 shows the condition when the pressure welding of the clad tubes is completed. As is clear from this figure, outer metal layers 1a, 1a' and inner metal layers 1b, 1b' are pushed to the inside and outside of each tube respectively, forming burrs 5 and 6.

When used for the plumbing or the like in chemical factories, this burr must be removed so that the flow of the liquid in the tube is not hindered. The burr is removed by a burr removing blade. The condition of the clad tube after removing the burr using a burr removing blade is shown in Fig. 11.

#### PROBLEM TO BE RESOLVED BY INVENTION

When clad tubes are joined together by currently known friction pressure weld methods, the outer metal layer will be strongly pushed to the inside and outside as shown in Fig. 10. Therefore, when the burrs are removed from the joined clad tubes, the outer metal layer will be exposed in locations B where the burrs are removed from the inside, and there is a problem that the characteristics of the clad tube will be lost in this area.

The purpose of this invention is to provide a clad tube joining method which can join clad tubes together without exposing the outer metal layer to the inside of the tube, and without causing cracking or creating a brittle hard alloy layer.

## MEANS FOR RESOLVING PROBLEMS

The present invention relates to a method for joining together ends of a plurality of clad tubes which are clad on the inside of an outer metal layer with an inner metal layer which is thinner than said outer metal layer and which clad tubes are pressed together in the condition of having the same center axis.

With the method of the present invention, a U-shaped groove is formed in the ends to be joined of the clad tubes to be joined, and friction contact between the inner metal layer of the clad tubes to be joined is first started and then both clad tubes are friction pressure welded.

The U-shaped grooves preferably have a groove angle greater than  $15^{\circ}$  and less than  $45^{\circ}$ .

As shown in Fig. 7(A), not establishing a curvature in the boundary region between the groove surfaces 10A, 10A' and the root faces 10B, 10B' is acceptable, and as shown in Fig. 7(B) through (D), establishing a curvature in the boundary region 10C, 10C' between the groove surfaces 10A, 10A' and the root faces 10B, 10B' is also acceptable. Furthermore, the radial dimension F of the root faces 10B, 10B' may be equal to the thickness c of the inner metal layer as shown in Fig. 7(A) and (B), or the radial dimension F of the root faces may also be smaller than the thickness c of the inner metal layer as shown in Fig. 7(C). Furthermore, as shown in Fig. 7(D), the radial dimension F of the root faces may also be set larger than the thickness c of the inner metal layer.

The outer metal layer is made from, for instance, carbon steel or chrome molybdenum steel and the inner metal layer is made from stainless steel or nickel alloy steel.

## FUNCTION

As described above, when a U-shaped groove is established in the ends of clad tubes to be joined, friction contact is started between the inner metal layers of the clad tubes to be joined, and then friction pressure welding of the clad tubes is performed, the pressure welding will proceed such that first a portion of the inner metal layer will move to the inward side of the tube and also to the groove, and therefore the inner metal layers can be positively joined together so that when the burr is removed from the inside of the tube, the external metal layer can be prevented from becoming exposed to the inside of the tube. Therefore, because of this invention, clad tubes can be joined together without losing the properties of clad tubes, making use of the characteristics of friction pressure welding without creating a brittle hardened metal layer in the joining region. Furthermore, the process is less inconvenient than when compared to arc welding, so the number of process steps required for joining can be reduced, and work efficiency can be increased.

## PREFERRED EMBODIMENTS

The preferred embodiments of this invention will be described below in detail while referring to the attached drawings.

Fig. 1 shows a cross-section near the end to be welded of clad tubes 10, 10' which were joined by a preferred embodiment of the present invention, and clad tubes 10, 10' are both made from an

**BEST AVAILABLE COPY**

outer metal layer 10a, 10a' and an inner metal layer 10b, 10b' which is clad over the inside of the outer metal layer. In this preferred embodiment, the end region of the outer metal layer on the ends to be welded of the clad tubes 10, 10' is cut on an angle around the whole circumference to form a groove surface 10A, 10A', and as shown in Fig. 2, when both ends to be joined of the clad tubes 10, 10' are firmly pressed together, a U-shaped groove 11 is formed in the joining region of both clad tubes.

The end surfaces of the inner metal layer 10b, 10b' of clad tubes 10, 10' form root faces (pressure welded surfaces) 10B, 10B' which are orthogonal to the axial line of both clad tubes, and when both ends to be joined of clad tubes 10, 10' are firmly held together through groove 11, only these root faces have planar contact.

When joining clad tubes 10, 10', one clad tube 10 is secured in a stationary side clamp established in a friction pressure welding device, while the other clad tube 10' is grasped in a rotationally driven main shaft chuck. The rotating side clad tube 10' is rotated while in pressed contact at a designated pressure (known as the heating pressure) to the other clad tube by a pressing device, and the contact regions of both tubes are heated by friction.

The pressing device may be established on either the rotating side or the stationary side, but in the preferred embodiment, the pressing device was established on the rotating side. In the friction pressure welding device used for the preferred embodiment, the main shaft which rotates the clad tube 10' and a stand which supports the drive mechanism or the like which rotates the main shaft are able to move in the axial direction of the main shaft, and the necessary pressing force between clad tubes 10, 10' is provided by applying a force to the stand by a pressing device which uses a hydraulic cylinder.

When the inner metal layers 10b, 10b' of clad tubes 10, 10' are held together and relative rotation is created between the two, the temperature of the joining regions will increase because of the heat of friction. Therefore, the inner metal layers 10b, 10b' will soften, so the region around the areas pressed together of the inner metal layers 10b, 10b' will be pushed out to the groove 11 side and the inside of the tube while simultaneously the clad tubes 10, 10' are brought together as shown in Fig. 3.

Furthermore, as time passes, the external metal layers 10a, 10a' will contact together from the valley side of the U-shaped groove 11 as shown in Fig. 4, and the outer metal layers 10a, 10a' will move to the outside through the groove, and clad tubes 10, 10' will be further brought together.

When the temperature of the joining regions reaches the designated temperature, the clad tube 10' on the rotating side will be stopped and the clad tubes 10, 10' will be pressed together with a large upset pressure by a pressing mechanism, and will be welded together. The total upset  $\delta$  from the start of rotation until the upset is complete shall be set to be sufficiently large so that the end regions 10A1, 10A2 (regions farthest away from the joint region) of the opening side of the groove surfaces will be completely joined as shown in Fig. 5.

In the condition of where the joint is completed in this manner, burrs 13 and 14 will be formed on the outer circumference side and the inner circumference side of the joint as shown in Fig. 5. Eventually these burrs are removed to achieve the condition shown in Fig. 6.

When executing the method of this invention, it is preferable that the groove angle  $\theta$  of the U-shaped groove 11 in a range between  $15^\circ$  and  $45^\circ$ . If the groove angle  $\theta$  is smaller than  $15^\circ$ , the amount of burr pushed to the inside of the tube will be large, which is not desirable. Furthermore, if the groove angle  $\theta$  is larger than  $45^\circ$ , the upset will be too large and the time required for a pressure weld will lengthen and operation efficiency will drop.

Tests performed in order to confirm the effect of the present invention will be described below.

#### Test 1

The clad tubes to be welded were clad tubes 10, 10' (conforming to US ASME standard 4B x Sch80) with carbon steel as the outer metal layer 10a, 10a' and stainless steel (SUS 304) as the inner metal layer 10b, 10b'. In this test, a groove was not formed, the rotational speed during heating pressure was 750 rpm, the heating pressure P1 was 2 kgf/mm<sup>2</sup>, the upset pressure P2 was 8 kgf/mm<sup>2</sup>, and the upset delta was 10 mm. After pressure welding, burrs were removed from the inside and outside of the tube, and when the joining region was cut and the cut was observed under a microscope, it was confirmed that the outer metal layer of carbon steel was exposed on the inside surface of the tube.

#### Test 2

The clad tubes to be welded were clad tubes 10, 10' (conforming to US ASME standard 3B x Sch80) with carbon steel as the outer metal layer 10a, 10a' and 70% Ni - 15 Cr alloy steel as the inner metal layer 10b, 10b'. In this test, a groove was not formed, the rotational speed during heating pressure was 750 rpm, the heating pressure P1 was 3 kgf/mm<sup>2</sup>, the upset pressure P2 was 12 kgf/mm<sup>2</sup>, and the upset delta was 10 mm. After burrs were removed from the inside and outside of the pressure welded tube, the joining region was cut and the cut was observed under a microscope, it was confirmed that the outer metal layer of carbon steel was exposed on the inside surface of the tube.

#### Test 3

The clad tubes to be welded were clad tubes 10, 10' (conforming to US ASME standard 4B x Sch80) with 2 1/4 Cr - 1 Mo steel as the outer metal layer 10a, 10a' and stainless steel (SUS 316) as the inner metal layer 10b, 10b'. The groove angle  $\theta$  was set to  $60^\circ$ , the rotational speed during heating pressure was 750 rpm, the heating pressure P1 was 3 kgf/mm<sup>2</sup>, the upset pressure P2 was 10 kgf/mm<sup>2</sup>, and the upset  $\delta$  was 14 mm. After pressure welding, burrs were removed from the inside and outside of the tube, and the joining region was cut and the cut was observed under a microscope. The results in the joining region confirmed that the inner metal layer was completely joined and the characteristics of the clad tube were not lost. Furthermore, when a nondestructive test of the joining region was performed using ultrasonic waves, defects such as cracks, blowholes, and improper fusing or the like were not found.

With the method of the present invention, various U-shaped grooves may be used. Fig. 7 (A) through (D) show several examples of U-shaped groove configurations which are used with the method of the present invention.

The example shown in Fig. 7(A) does not have a curvature (no radius) in the boundary region between the groove surfaces 10A, 10A' and the root faces (groove end surface) 10B, 10B', and the example shown in Fig. 1 through Fig. 6 used the U-shaped groove shown in Fig. 7(A).

Furthermore, the examples shown in Fig. 7 (B) through (D) have a curvature in the boundary region 10C, 10C' between the groove surfaces 10A, 10A' and the root faces 10B, 10B'.

Dimension F in the radial direction of root faces 10B, 10B' may be equal to the thickness C of the inner metal layer 10b, 10b' as shown in Fig. 7 (A) and (B), or may be smaller than the thickness C of the inner metal layer 10b, 10b' as shown in Fig. 7 (C). Furthermore, dimension F in the radial direction of root faces 10B, 10B' may be larger than the thickness C of the inner metal layer 10b, 10b' as shown in Fig. 7 (D).

Generally, the material thickness t of this type of metal tube in the range of 5 ~ 30 mm, and the thickness C of the inner metal layer is in the range 2 ~ 3 mm (However  $t > C$ ).

Dimension F in the radial direction of root faces 10B, 10B' is dependent on the thickness C of the inner metal layer 10b, 10b', but normally is preferably set to the range 1 ~ 10 mm. Furthermore, the curvature radius when a radius is established in the boundary region between the groove surface and the root face is preferably set to 1 ~ 5 mm.

In the above preferred embodiments, after the clad tubes 10, 10' are firmly held together and rotated to heat, the moment the joining region reaches the designated temperature, rotation of the clad tube is stopped and then the upset is performed, but it is also acceptable to temporarily increase the pressure during heating rotation, and then finally rapidly increase the pressure.

In the above description, one of the clad tubes 10, 10' was stationary and the other was rotated, but the method of rotating during heating rotation is arbitrary and various previously proposed rotating methods for friction pressure welding may be used. For instance, it is also acceptable to rotate clad tubes 10, 10' in opposite directions.

In the above preferred embodiments, the case of the joining two clad tubes 10, 10' was used, but the method of the present invention can also be applied to the case where 3 clad tubes are successively pressed together and friction pressure welding performed by creating relative rotation between the center clad tube and the clad tubes on both sides, by establishing grooves in each of the joining regions.

#### EFFECT OF THE INVENTION

As described above, with this invention, a U-shaped groove is established in the outer metal layer region of the ends of clad tubes to be joined, and friction contact between the inner metal layers of the clad tubes to be joined is first made and then the clad tubes are friction pressure

welded, and therefore the inner metal layers are positively joined to each other and exposure of the outer metal layer to the inside surface of the tube can be prevented when the burr is removed from the inside of the tube. Therefore, the characteristics of the clad tube will not be lost, the characteristics of friction pressure welding can be taken advantage of, and clad tubes can be joined together without creating a weak and hard metal layer in the joining regions.

Furthermore, when compared to arc welding, this method is advantageous because it is less inconvenient and the operating efficiency can be increased.

#### 4. BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-section view showing the cross-section shape of the region around the joining region of clad tubes which have been joined by the method of this invention, Fig. 2 through Fig. 6 are cross-section views schematically showing the cross-section shape of the joining region when clad tubes are joined together using the method of this invention, Fig. 7 (A) through (D) are cross-section views showing various examples of groove configurations which use the method of this invention, Fig. 8 is a cross-section view schematically showing the section shape of the joining region when clad tubes are joined by arc welding, and Fig. 9 through Fig. 11 are cross-section views showing the change in the cross-sectional shape of the joining region when clad tubes without grooves are friction pressure welded.

10, 10' -- clad tubes, 10a, 10a' -- outer metal layer, 10b, 10b' -- inner metal layer, 11 -- U-shaped groove, 13, 14 -- burr,  $\theta$  -- groove angle.

Agent MATSUMOTO, Hidetoshi Attorney (and 1 other)

Figure 1

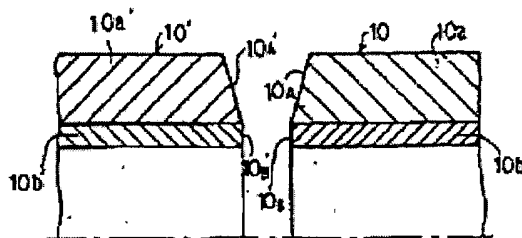


Figure 2

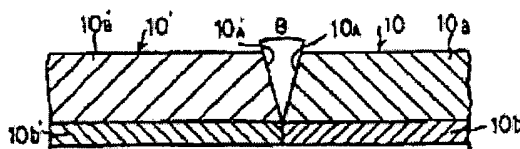


Figure 3

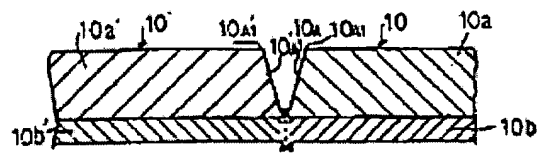


Figure 4

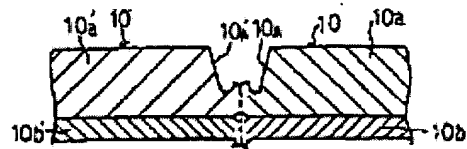


Figure 5

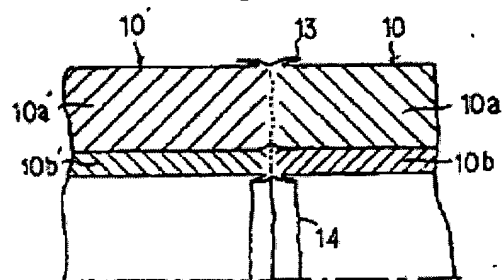


Figure 6

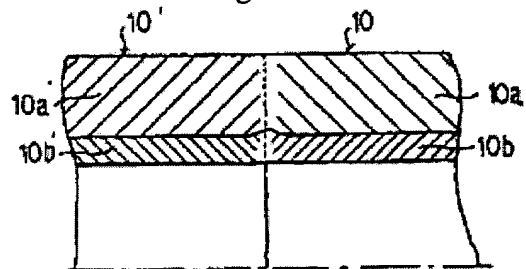


Figure 7

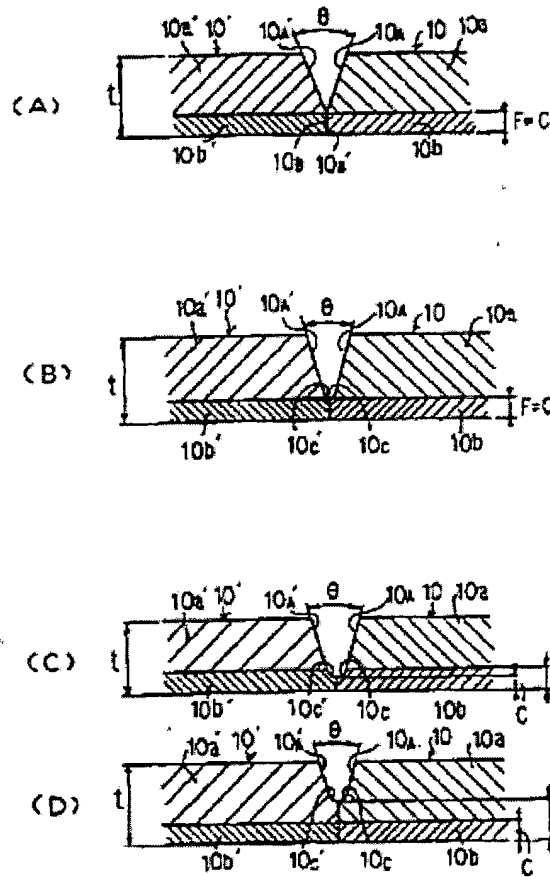


Figure 8

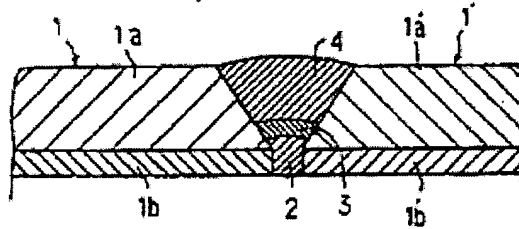


Figure 9

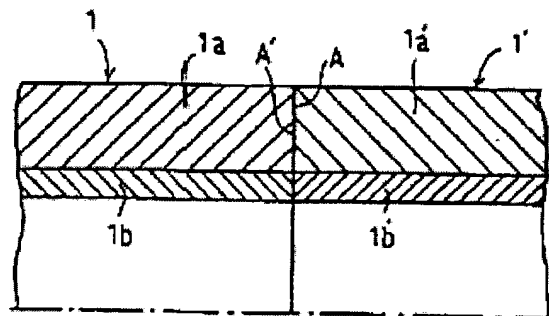


Figure 10

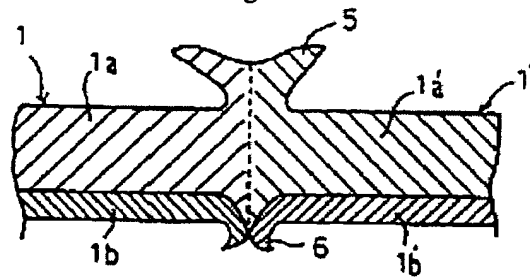
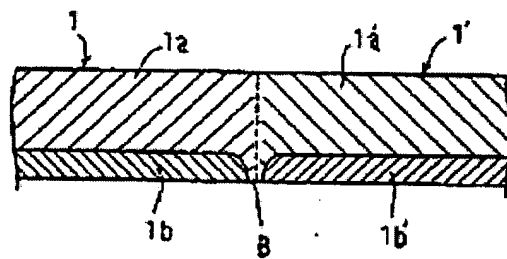


Figure 11



BEST AVAILABLE COPY

**THIS PAGE BLANK (USPTO)**